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KNAPWEED RESPONSE TO DISTURBANCE IN PONDEROSA PINE/DOUGLAS-FIR FORESTS

By Dr. Cathy Zabinski

FINAL REPORT FOR RESEARCH AGREEMENT
INT-97059-RJVA
"Knapweed Response to Disturbance in Ponderosa Pine/Douglas-fir Forests"
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Knapweed Response to Disturbance in Ponderosa Pine/Douglas-Fir Forests

Final Report, INT-97059-RJVA
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The spread of exotic plants into native vegetation depends on the autoecology of the invasive plant, the resource availability and disturbance patterns of the environment being invaded, and interactions with established vegetation (Higgins and Richardson 1996). The relationship between weed invasion and disturbance is underscored by the distribution of weeds along roadsides and on cultivated and grazed lands. Both anthropogenic and natural disturbances serve to open habitat suitable for colonization by invasive species, and the pattern and size of those disturbances affect the rate of invasion (Bergelson et al. 1993). This report summarizes a preliminary study designed to test the effects of two kinds of disturbance--skid trails and fire--on knapweed distribution in Ponderosa pine/Douglas fir forests.

Spotted knapweed *(Centaurea maculosa)* is an invasive species that has impacted millions of acres of rangeland in western Montana and Idaho (Muller-Scharer and Schroeder 1993). Characteristics that enhance its ability to spread are prolific seed production (Schirman 1981), ability of seeds to survive in the soil for at least seven years (Davis et al 1993), and in some habitats to germinate during moist fall periods and overwinter as seedlings (Lacey et al. 1990, and pers. observation).

While the phenomenon of knapweed invasion into western grasslands has been fairly well documented (Lacey et al. 1990, Wright and Kelsey 1997), little is known about the spread of knapweed into low elevation Ponderosa pine stands. Ponderosa pine forests are fire-dependent ecosystems that have been severely impacted by fire suppression policies of the last 60-80 years (Arno et al. 1995a). While historically these were open, park-like stands with relatively frequent understory burns, fire suppression has resulted in an increase in basal area, and a shift to shade tolerant trees, such as Douglas fir, that form dense thickets in the understory (Arno et al. 1995b).

Forest researchers are investigating methods to manage these fire-suppressed ecosystems, including thinning the stand through harvesting and reintroducing fire. While early results from this approach seem highly successful, the effect of both harvesting activities and fire on the spread of knapweed in these newly opened stands need to be investigated. This is especially crucial for low elevation forests that exist in close proximity to grasslands and roadways with high weed densities. Logging activities present opportunities for weed invasion into forested

areas, as roads and skid trails function as corridors for weed propagules. Additionally, there is evidence that in some systems fire can enhance the invasion of exotic species into areas of native vegetation (Milberg and Lamont 1995). The effects of burning and skid trails on vegetation in Ponderosa pine stands was investigated at Lick Creek during the summer of 1997. The primary focus was on the effects of environmental parameters and management practices on knapweed density, but we also considered the effects of management practices on the distribution of other understory species as well.

Study site

Lick Creek Demonstration Area is located on the Bitterroot National Forest in Western Montana (46°5' N., 114°15'W). The dominant overstory species include Ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menzieseii*), lodgepole pine (*Pinus contorta*), grand fir (*Abies grandis*) and subalpine fir (*Abies lasiocarpa*) at the higher elevations. In 1991, a study was established at Lick Creek to evaluate the efficacy of shelterwood cutting and prescribed burning to enhance second-growth Ponderosa pine stands. Within the shelterwood cut, three burn treatments were established: no burn, moist burn, and dry burn. The shelterwood cut was done with traditional forestry practices, including the use of a skidder on all but the steepest slopes.

METHODS

A skid trail was identified within each of the contrasting burn treatments, using Plots 1, 2 and 7 as representative of moist burn, no burn and dry burn, respectively. Skid trails were selected for this study that began near the lower road and went up-slope. Five transects running perpendicular to the skid trail were established at random intervals. The transects were 14 m in length, with the 8m point at the center of the skid trail. At 2-meter intervals along the transect (0m, 2m, 4m, 6m, 8m, 10m, 12m, 14m) the following data were collected: slope, aspect, canopy cover, species present and their percent cover within a 1 m quadrat, percent cover of bare ground and litter, and a count of knapweed plants. We sampled one skid trail per burn treatment, with five transects per skid trail, and eight plots per transect, for a total of 40 plots per burn treatment, and 120 plots overall.

The slope was measured using a clinometer. Canopy cover was calculated with a spherical crown densiometer. Species, bare ground, and litter cover were recorded using the following categories: 0 -- trace; 1 -- 1 to 10 percent cover; 2 -- 11 to 25 percent cover; 3 -- 26 to 50 percent cover; 4 -- 51 to 75 percent cover; 5 -- 76 to 100 percent cover. Knapweed plants were counted in each m^2 plot.

Statistical analysis. ANOVA was used to test for differences between slope, canopy, aspect and knapweed density across the three burn treatments. For slope, aspect, and knapweed density data, Kruskal-Wallis ANOVA on Ranks was used, because data did not meet normality

and equal variance requirements after transformation. Dunn's method of multiple comparison at 0.05 level of significance was used as a post hoc comparison. Percent cover data was tested with One Way ANOVA, with a Tukey test for all pairwise multiple comparisons. ANOVA results should be interpreted with caution, since plots were not independently distributed. Although transects were located at random intervals along each skid trail, plots along the transect were placed at 2m intervals, and only one skid trail was sampled per burn treatment.

Bar plots were used to summarize the relationship between environmental parameters and burn treatments, and knapweed density and burn treatments. Error bars represent the standard error of the mean. Scatter diagrams were used to illustrate the relationship between knapweed density and environmental parameters. While you cannot test for significance, scatter diagrams allow for a visual assessment of patterns in the data.

The effect of skid trails on vegetation was plotted for knapweed density, and for the remainder of the species, on occurrence data. The presence of the most common species, those occurring in at least 10 of the 40 plots on one or more of the burn treatments, was summed across all transects and all burn types. The relationship between fire and vegetation occurrence was summed across location within a transect, i.e., irrespective of skid trail effects. Therefore the simultaneous comparison between skid trails and burning was only examined using the data on knapweed density data.

RESULTS

The species list is included in Table 1. There was a total of 69 taxa (identified to species or genera). The most common species are noted by an asterisk in Table 1.

Knapweed density as affected by environmental factors

A description of the three burn treatments, and the relationship between knapweed density and environmental parameters, including slope, aspect, canopy cover, and percent mineral soil is summarized in Figures 1-6. Percent slope ranged from 0 to 41% across the three burn treatments. The mean slope of the three burn treatments differed significantly (Kruskal-Wallis One Way ANOVA, $p<0.001$), with an 11% slope in the no burn treatment, 18% in the moist burn, and 16% in the dry burn treatment (Figure 1). Knapweed occurs on slopes that range from 3 to 31%, with the most dense occurrence of knapweed plants ($261/m^2$) on a slope of 31% (Figure 2). Meter-square plots with no knapweed were found across the entire range of slopes.

Aspect of the plots ranged from 130° to 270°, with the majority of the plots facing SE. The average aspect of the three burn treatments was southerly (Figure 3), but differed significantly (Kruskal-Wallis One Way ANOVA, $P<0.001$), with no difference between the burn sites which faced S-SE (an average of 160° in the moist burn and 165° in the dry burn) but a difference at the 0.05 level in the no burn treatment, which faced S-SW (200°). From the data set in hand, it appears that knapweed occurs more commonly on SE aspects, as only one plot

Table 1. Species List. Species with an * occurred in at least ten plots in one or more of the burn treatments.

TREE/SHRUB	GRAMINOID	FORB	OTHER
Conifer sp	Agropyron repens	Achillea millefolium*	Lycopodium sp.
Picea engelmannii	Agropyron sp.	Anaphalis margaritacea	
Pinus ponderosa*	Agropyron spicatum	Apocynum androsaemifolium	
Pseudotsuga menziesii	Agrostis alba	Aquilegia sp	
Arctostaphylos uva-ursi*	Agrostis scabra	Arabis sp.*	
Berberis repens*	Bromus sp.	Arnica cordifolia	
Menziesia ferruginea	Calamagrostis rubescens*	Aster sp.*	
Purshia tridentata	Carex geyeri*	Campanula sp.	
Rosa sp.*	Deschampsia elongata	Centaurea maculosa*	
Rubus idaeus	Festuca idahoensis	Cirsium sp.*	
Salix sp.	Festuca occidentalis	Epilobium angustifolium	
Shepherdia canadensis*	Festuca sp.	Epilobium sp. 1*	
Spirea betulafolia*	Juncus ensifolius	Epilobium sp. 2	
Symphorcarpus albus*	Juncus sp.	Erigeron sp.	
Vaccinium caespitosum	Phleum sp.	Fragaria virginiana*	
Unknown shrub	Poa compressa	Gallium boreale	
	Unknown graminoid	Hieracium albertinum*	
	Unknown sedge	Holodiscus discolor	
		Lupinus sp*	
		Osmorhiza chilensis	
		Penstemon albertinus*	
		Plantago sp.	
		Polygonom sp.*	
		Prunella vulgaris	
		Rumex sp.	
		Sedum lanceolatum	
		Silene menziesii	
		Solidago sp.	
		Taraxacum officinale	
		Thalictrum sp.	
		Tragapogon dubius	
		Trifolium sp.	
		Verbascum thapsis*	
		Veronica arbensis	
		Viola sp.	
		Unknown	

with an aspect greater than 180° had any knapweed plants (Figure 4). Knapweed occurred primarily on aspects between 140° and 180°. These results conflict with that of Losensky (1987) who shows that SW aspects have the highest risk for knapweed invasion.

Canopy cover ranged from 48% to 80%, across all plots, and varied significantly across the burn treatments (1-way ANOVA, $F=14.010$, $p<0.001$). Cover was 59% on the no burn treatment, 64% on the dry burn treatment, and 65% on the moist burn site (Figure 5). Knapweed occurred on plots with canopy cover ranging from 52% to 77% (Figure 6).

Mineral soil was measured in cover classes, and the relationship between knapweed density and mineral soil cover is summarized in Figure 7. Knapweed occurred in plots across the range of mineral soil coverage. There were only three plots with greater than 50% exposed mineral soil, and they each had a low density of knapweed (2 with 2 knapweed plants/m^2 and the third with 9 knapweed/m^2).

Fire treatment and knapweed density

Knapweed density across the three burn treatments is summarized in Figure 8. Density was higher in the burn treatments than in the no burn treatment. Kruskal-Wallis One Way ANOVA on ranks showed a significant treatment effect ($P<0.001$). The burn treatments were not significantly different from each other at the 0.05 level, but were both different than the no burn treatment (Dunn's Multiple Comparison Procedure).

native

Vegetation response to fire

Species response to burn treatment was determined by summing the number of occurrences of the most common species over the 40 plots in each burn treatment. Species were categorized according to their response: positive, negative, neutral, and ambiguous. Those species with a positive response include four non-native species--knapweed, thistle, hawkweed, and mullein--and three native species: yarrow, Epilobium, and lupine (Figure 9). Mullein and yarrow both increased in the dry burn plot, but not in the moist burn plot. Knapweed and Epilobium showed the most pronounced response. Oregon grape and spirea both declined in burn treatments (Figure 10), with Oregon grape showing the most pronounced decline. The remaining species showed ambiguous responses (Figure 11), either peaking in the moist burn plots relative to no burn and dry burn, or declining in the moist burn plots relative to the other two treatments.

Vegetation response to skid trails

The number of occurrences of the most common species was summed across all fifteen transects in the three burn treatments. Data was plotted as the number of occurrences in 15 replicate plots across the 14m transect. All transects were established with the 8m point at the center of the skid trail. Species were classified into one of three categories: positive response to skid trail (Figure 12), negative response to skid trail (Figure 13), and no clear response (Figure 14).

Five of the twenty species showed a positive response, i.e., had a higher number of occurrences on skid trails than off skid trails. They include both non-native species--knapweed and thistle--and native species--buffaloberry, lupine, and penstemon. Knapweed showed the strongest response, and lupine the

weakest. There was an equally high number of occurrences of lupine in 8m and 0m plots, which were well off of the skid trails. It occurred in all plots in trace and low amounts (1 to 10 percent cover) except for a single plot which had a cover class of 10 to 25%, and was not on a skid trail.

An additional five species showed a negative response to skid trails, by having the lowest occurrence on or adjacent to the skid trail. These were all native species, including Ponderosa pine seedlings, Oregon grape, rose, snowberry, and elk sedge. Elk sedge occurred in all 15 of the plots that were at the 0 and 2m intervals, and 11 of the plots at both the 6 and 8m intervals. Ponderosa pine occurred in only two of the fifteen plots that were located in the middle of the skid trail. The remainder of the species had no clear response to skid trails, and this list includes native and non-native species: mullein, polygonum, hawkweed, aster, arabis, yarrow, Epilobium, strawberry, bearberry, spirea, and pine grass.

Knapweed density relative to fire and skid trails

Knapweed density at each plot along the transects was averaged across the five replicates in each burn treatment, to address the question of interaction between skid trails and burn treatment (Figure 15). The no-burn treatment had a total of 22 knapweed plants found within the quadrats, 21 of which were on the edge of a skid trail, in a 6m plot, with one found within an 8m plot. The moist burn site had higher levels of knapweed, with a mean at the center of the skid trail of 25 plants/m^2. The dry burn site shows a distinct peak at the 8m point, with an average of 61 plants/m^2. The single plot with 261 knapweed plants was found within the dry burn treatment.

DISCUSSION

The results of this study must be interpreted as preliminary at best, since there was only a single replicate of each of the burn treatments, and sample size precludes statistical analysis for most of the comparisons. That said, this pilot study reveals some interesting trends that warrant further consideration.

The relationship of knapweed density to environmental parameters, including slope, aspect and canopy cover was fairly inconclusive in this study. The limitation of no replicates is especially illustrated in comparing environmental parameters on the three burn treatments (Figures 1, 3 and 5). The no-burn treatment differed significantly in slope, aspect and canopy cover from the two burn treatments. Slope was lower on the no-burn treatment, which would, according to Losensky's survey (1987) imply lower invasibility. However the other two environmental variables--canopy cover, which was lower, and aspect, which was S-SW--would imply higher invasibility on the no-burn plot (Losensky 1987). The no-burn treatment had the lower levels of knapweed than either of the burn treatments, but whether that is a result of the effects of fire on understory vegetation and litter layer, or inherent differences between sites, not related to the burn treatment, cannot be determined from this study.

Knapweed was present under a canopy cover of up to 80%, and canopy cover does not appear to be a significant environmental variable in determining the density of knapweed in this study. This is an important result, because it implies that forested stands are invasible by knapweed, at least with respect to

canopy cover. The possible implication of this is that competition with understory vegetation or surface organic matter may be what limits the speed of knapweed invasion into these habitat types relative to grassland invasion.

The relationship of knapweed to environmental parameters was studied by Chicione et al. (1985), on a statewide scale, considering soil characteristics, elevation, annual precipitation, potential evapotranspiration, length of frost-free season, and mean maximum July temperature. They considered a the value of a parameter to be predictive of knapweed presence if it occurred in at least 70% of the 116 sites of knapweed infestation across Montana. Chicione et al. (1985) concluded that knapweed density was determined by a complex interaction of environmental variables, since no single variable correlated well with knapweed distribution.

Vegetation response to fire, as determined by summing the number of occurrences on contrasting burn treatments, showed some interesting patterns. That 11 of the most common species showed an ambiguous response to fire, increasing in one of the burn treatments relative to the other, implies that species are either very exacting in their response to moist versus dry burns, or that vegetation is responding to site heterogeneity in the burn treatments, adding noise to the data on response to fire treatments. Increased sampling could clarify that concern. That the two species which showed the strongest response to fire treatments were knapweed and Epilobium suggests a relationship between knapweed invasion and fire. This especially warrants further study.

Skid trails are important corridors through a harvested stand, because they serve as a seedbed for seed carried on the tires of logging equipment, and they represent a severely disturbed environment, where much of the surface organic matter has been removed and the upper surface of the soil has been scarified. Three weedy species were not affected by the presence of skid trails, including mullein, polygonum, and hawkweed, but two weedy species increased in response to skid trails, including knapweed and thistle. There were also three native species that showed a potential increase in occurrence on skid trails, and may also be taking advantage of the scarified soil surface: penstemon, buffaloberry, and lupine. All of the species that showed a lower number of occurrences on rather than off skid trails were native species.

Knapweed's response to the combination of fire and skid trails warrants further study in a replicated design. Skid trails are one source of invasion into Ponderosa pine stands. The results of earlier field surveys (See October 31 Progress Report) suggest that knapweed is not extensively colonizing Ponderosa pine stands that have been burned within the previous five years, except on areas that have been heavily scarified (personal observation). It may be that five years is not enough time for knapweed to spread, or that knapweed in Ponderosa pine stands is most responsive to conditions that include both fire and serious ground scarification, or that knapweed responds to skid trails and fire is not a factor.

STUDY RECOMMENDATIONS

This study could be completed by measuring vegetation and environmental factors in replicate burn treatments at Lick Creek, and by expanding the study to include a second site that has had similar

shelterwood cutting in combination with burn treatments, such as Bear Fred Burr site. This would allow us to test the hypotheses that knapweed density is higher in burn treatments, and that skid trails or other forms of scarification serve as the point of infection into these stands. It is important from a management perspective to understand the relationship between fire and harvesting impacts on knapweed density. While harvesting methods can be altered (i.e., harvesting sites that are in close proximity to weed source during the winter), fire is a fact in western forests, either as prescribed burn or as wildfire.

By studying knapweed in the context of other vegetation, we may be better able to understand how knapweed is functioning ecologically. For example, knapweed and Epilobium show similar response to fire treatments, but not to skid trails. By comparing native and invasive species, we may be able to better discern how skid trails or scarified areas are serving as a point of infection, and under what conditions invasive plants are able to move off of those points of infection into native vegetation.

The field survey at the start of this project showed that knapweed was present in only small amounts in recently burned stands, and that it was present on seriously scarified areas within the stand (Zabinski, Progress Report 10/97). Patterns of knapweed occurrence at Lick Creek illustrate the fact that low elevation Ponderosa pine stands are invasible. We may be at a point in these communities that we were at 50 years ago with grassland invasion--at a very early stage where knapweed invasion is not a serious problem. This is an important time to study knapweed invasion into Ponderosa pine forests, to enable us to better predict points of infection and patterns of spread, and to mitigate the problem before knapweed reaches the levels it has in much of our rangeland.

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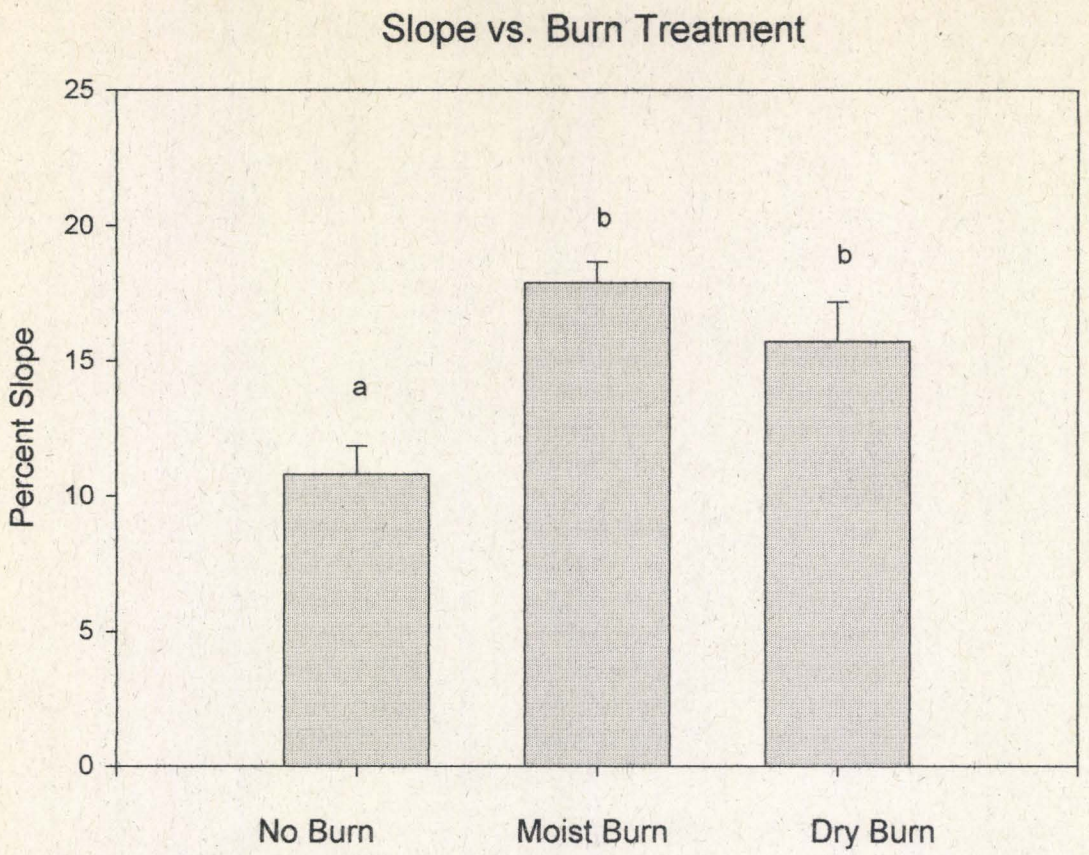
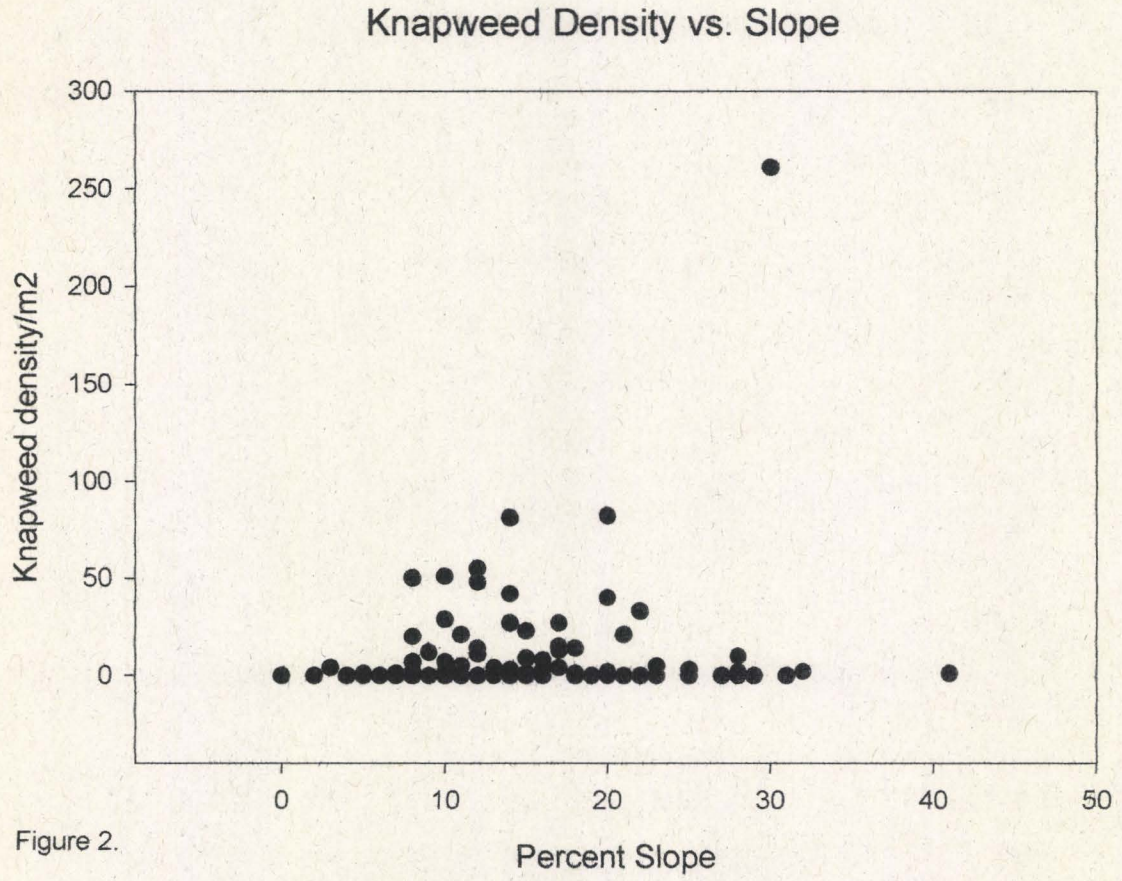


Figure 1.



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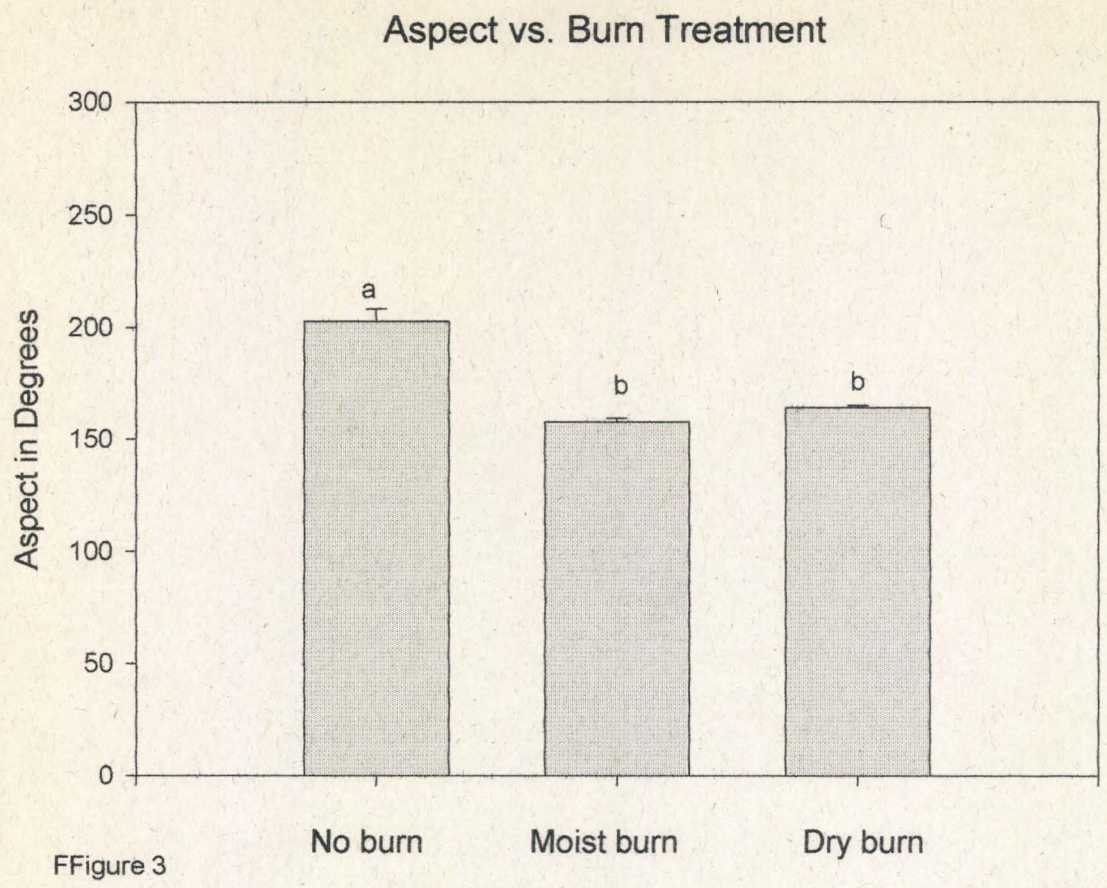

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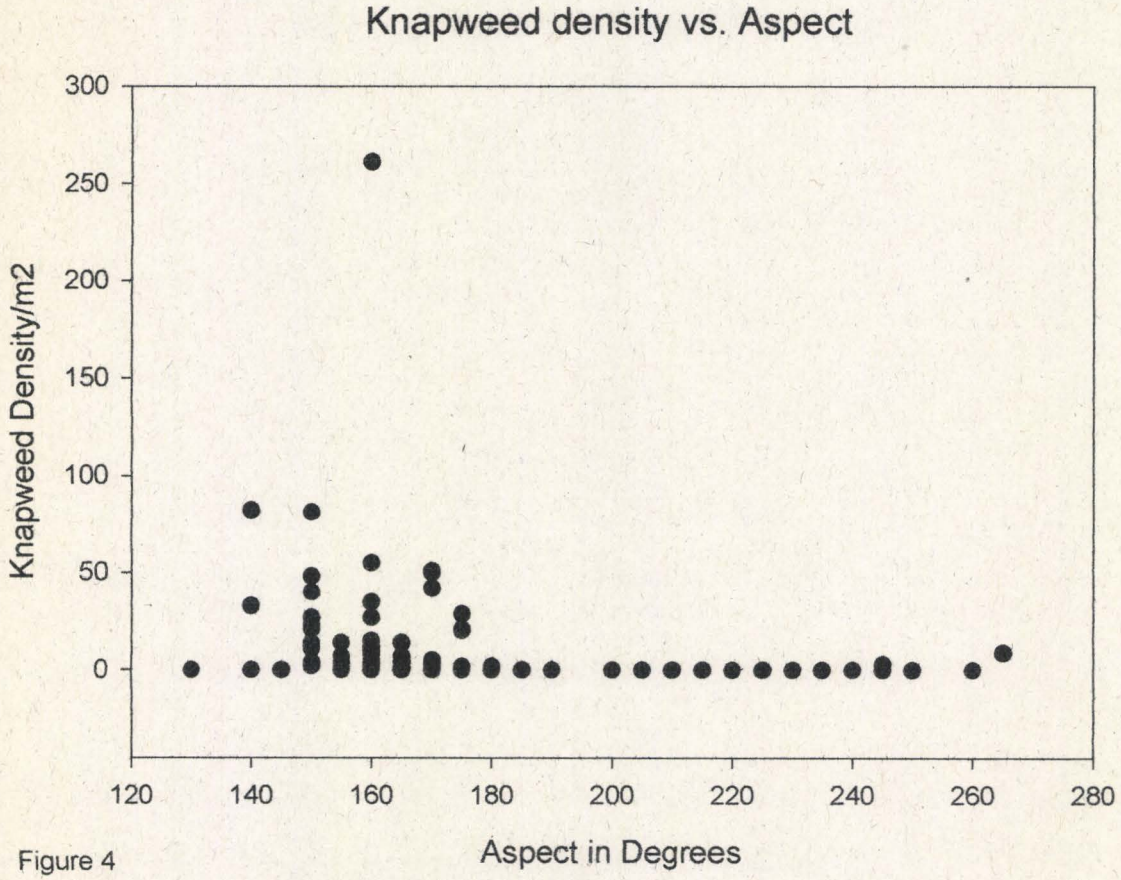


Figure 4

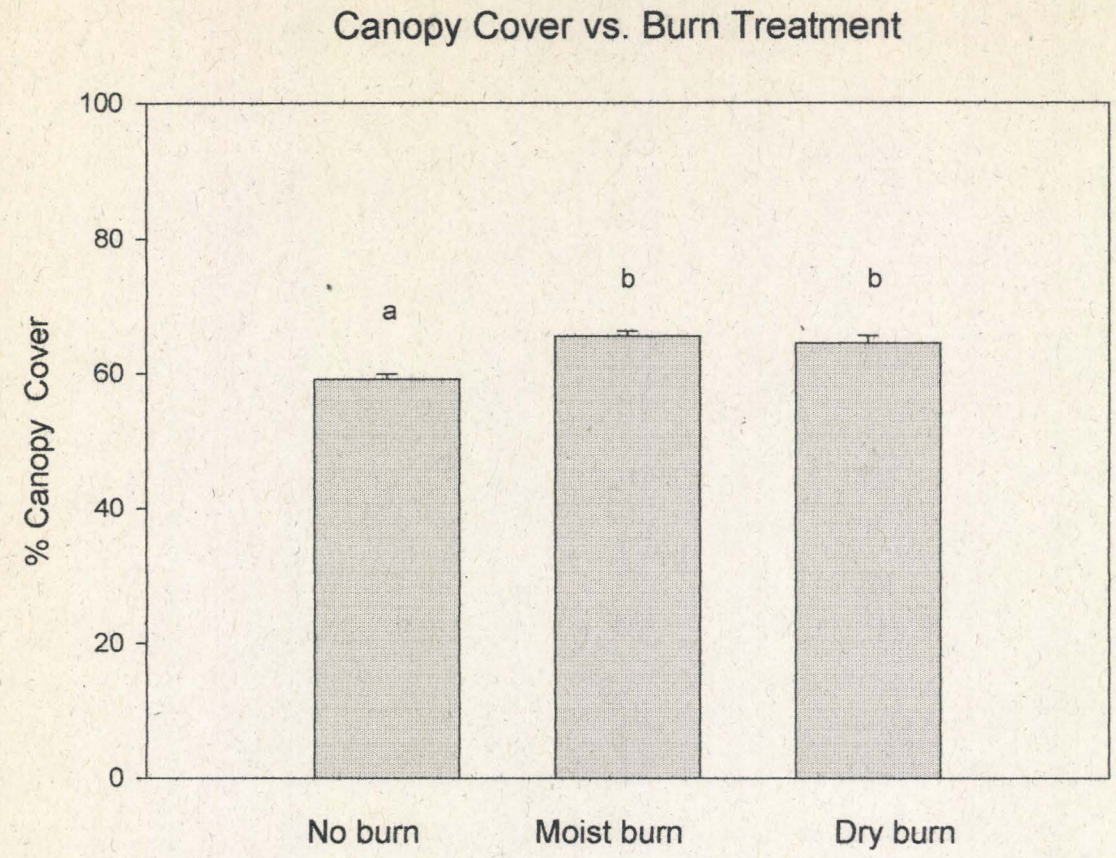
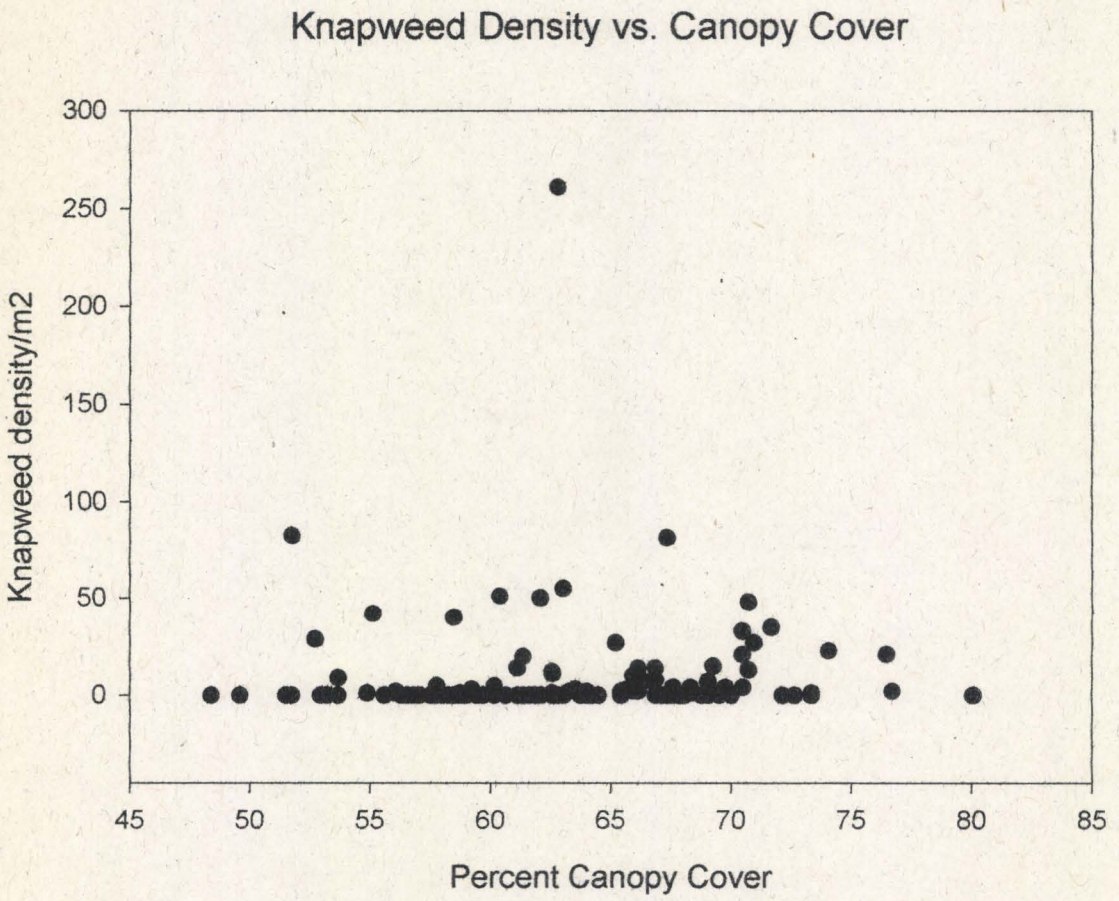


Figure 5.



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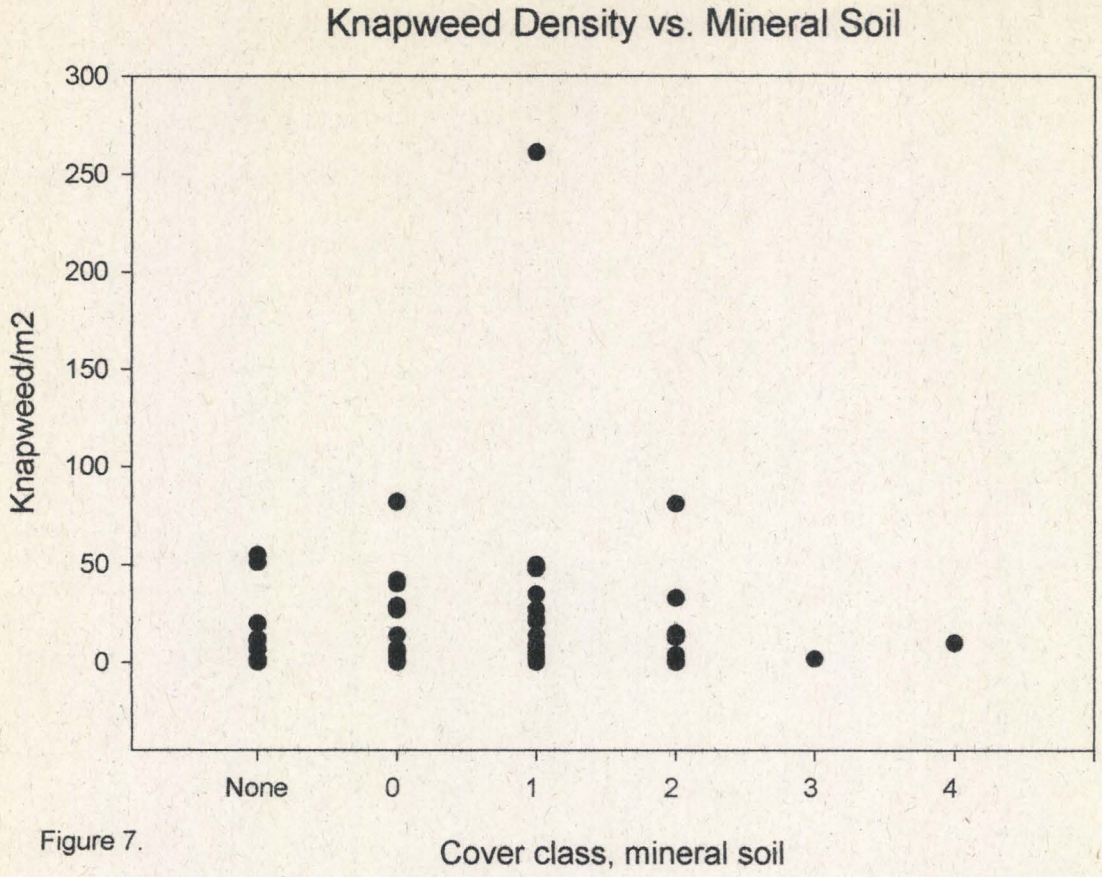


Figure 7.

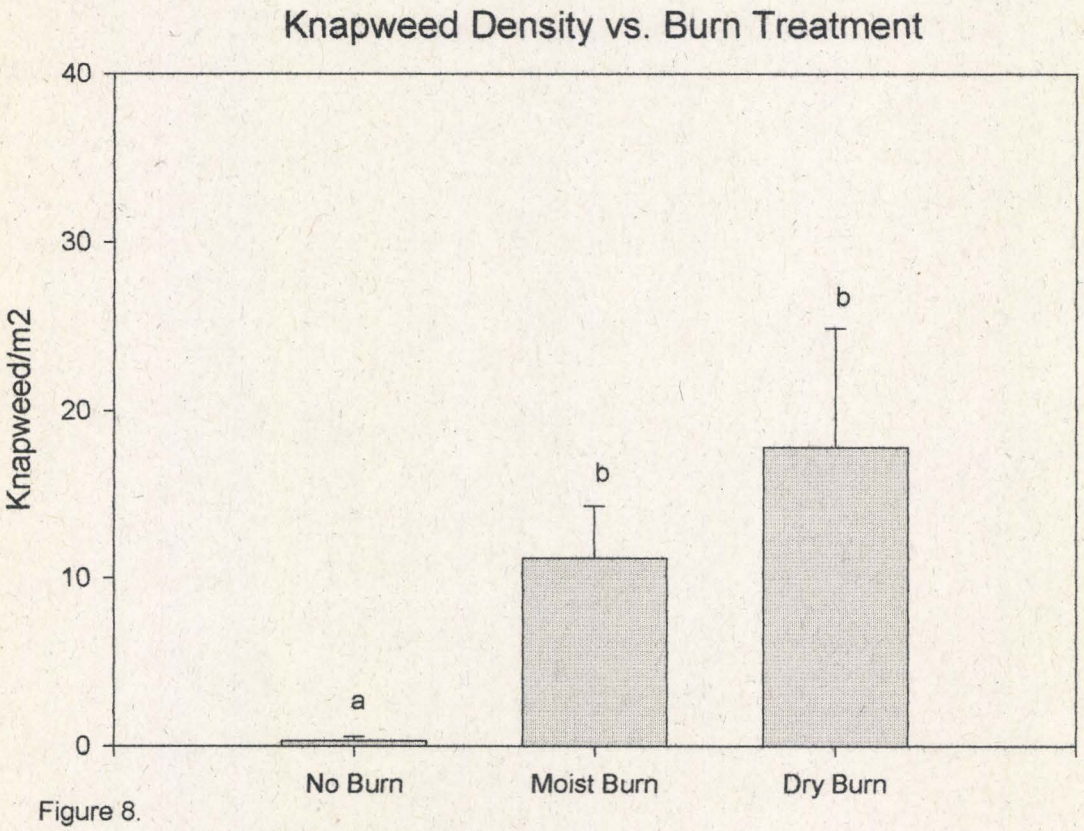


Figure 8.

Figure 9. Species with Postive Response to Fire

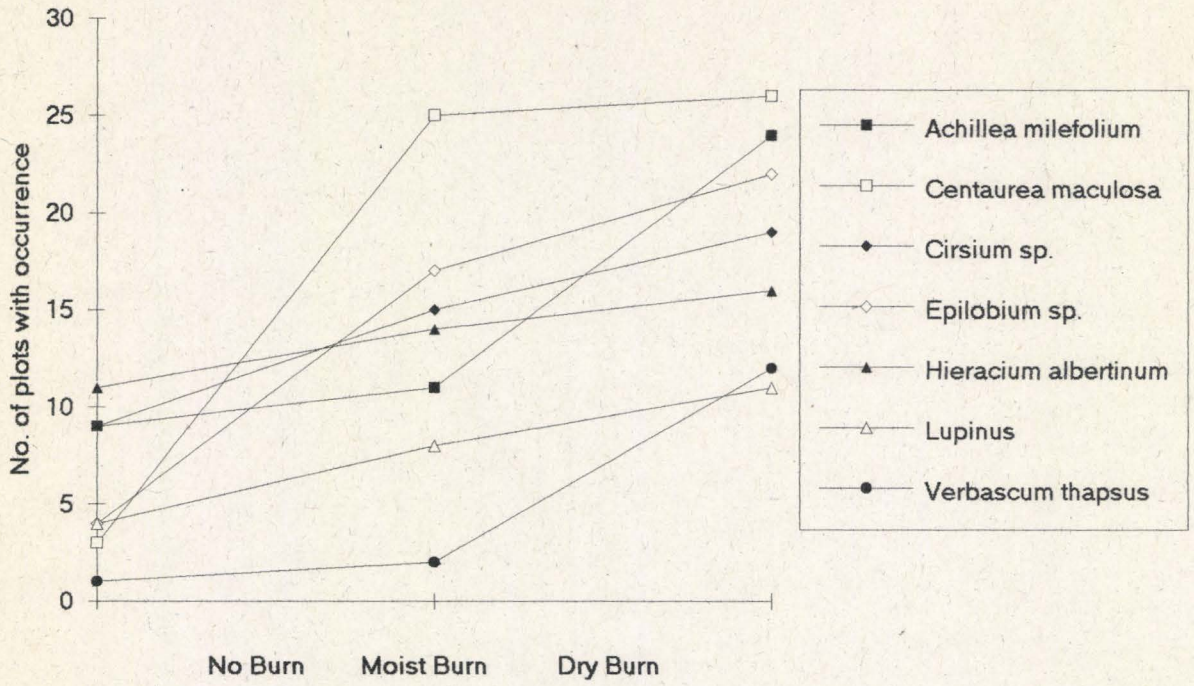


Figure 10. Species with Negative Response to Fire

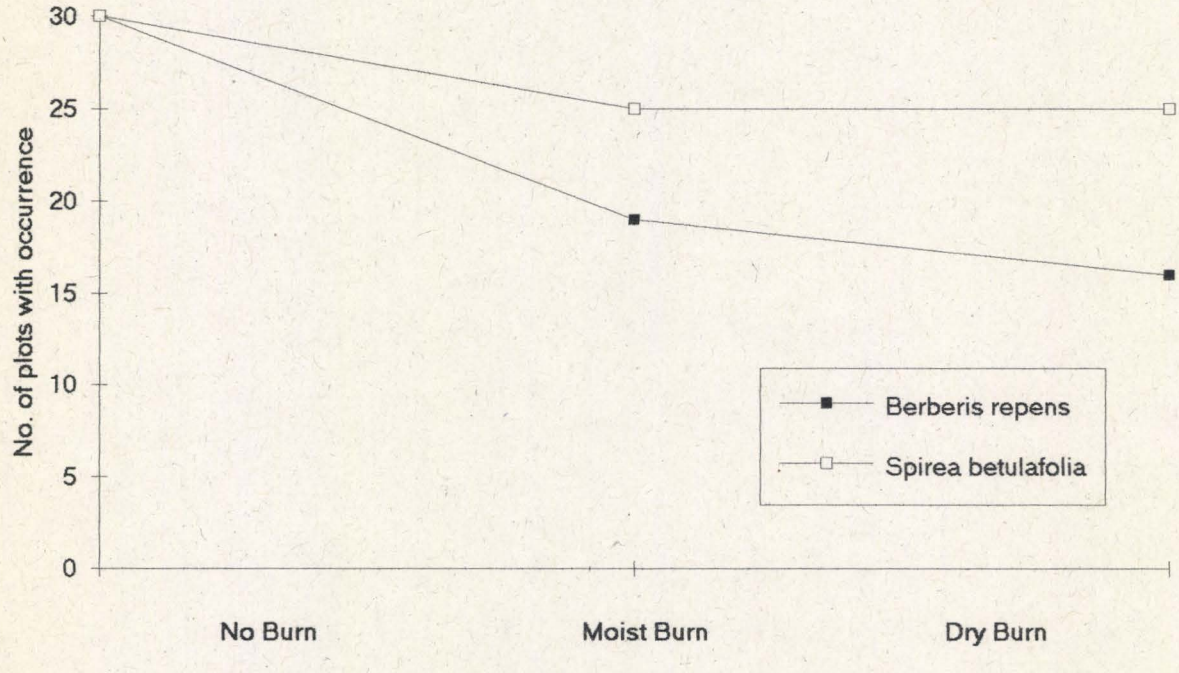
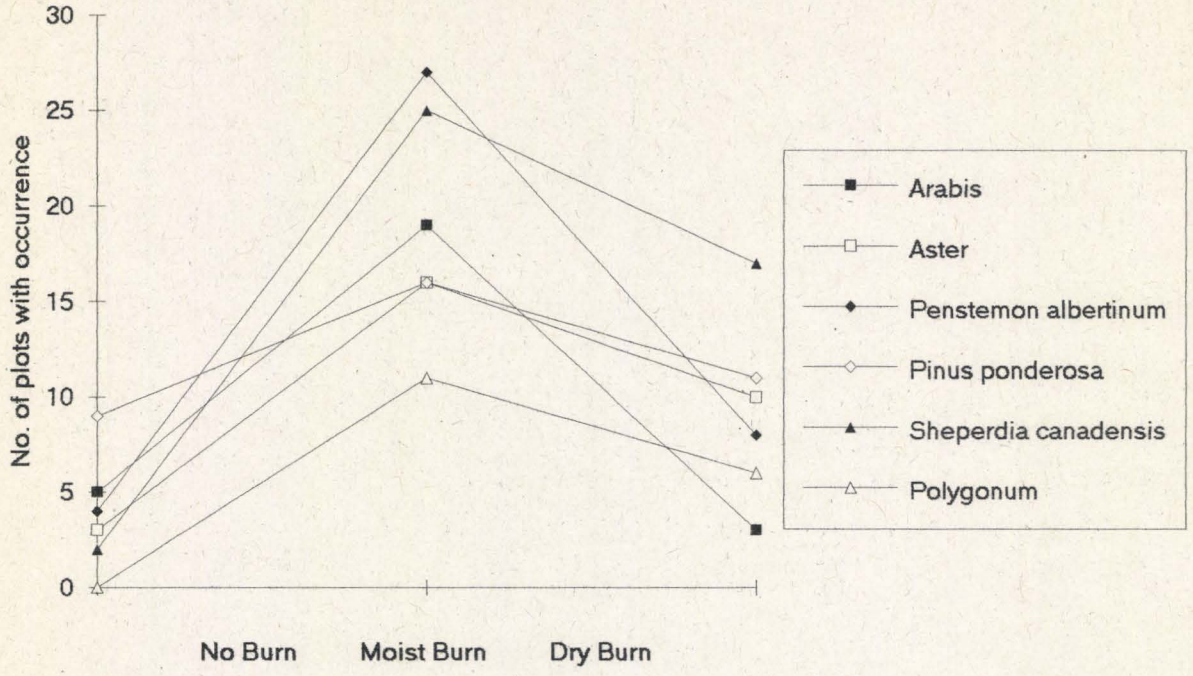


Figure 11. Species with Ambiguous Response to Fire.



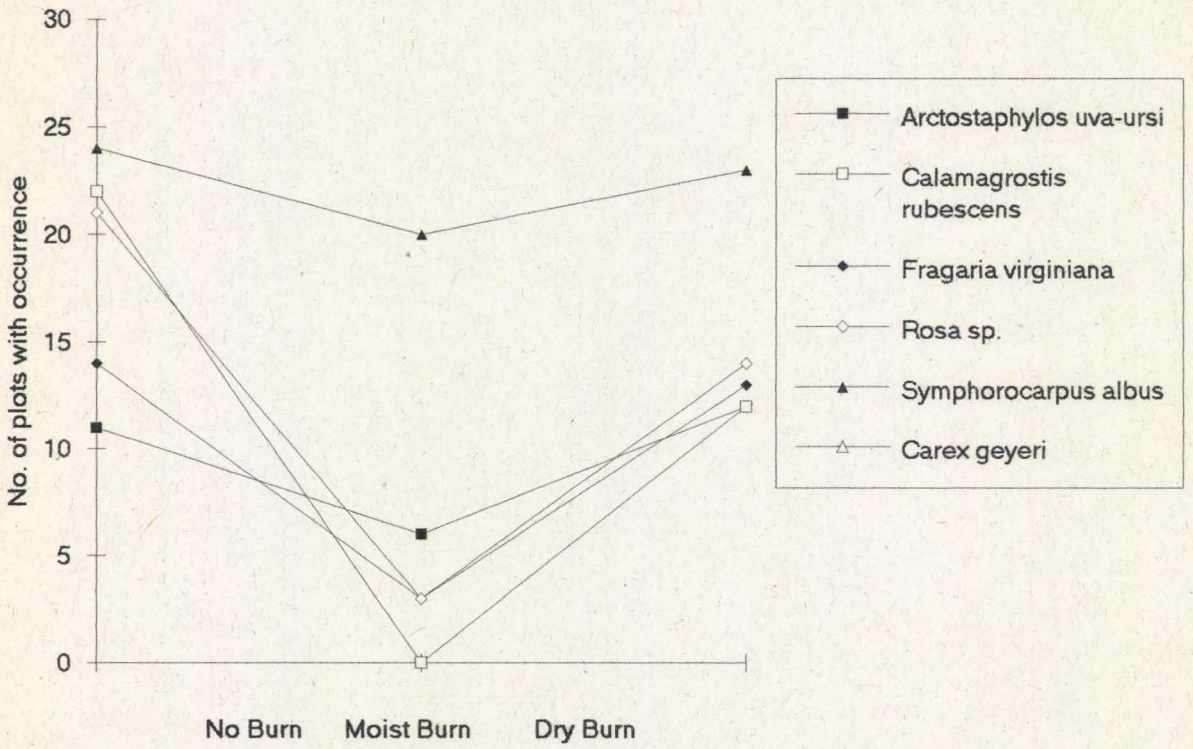


Figure 12. Species with positive response to skid trails

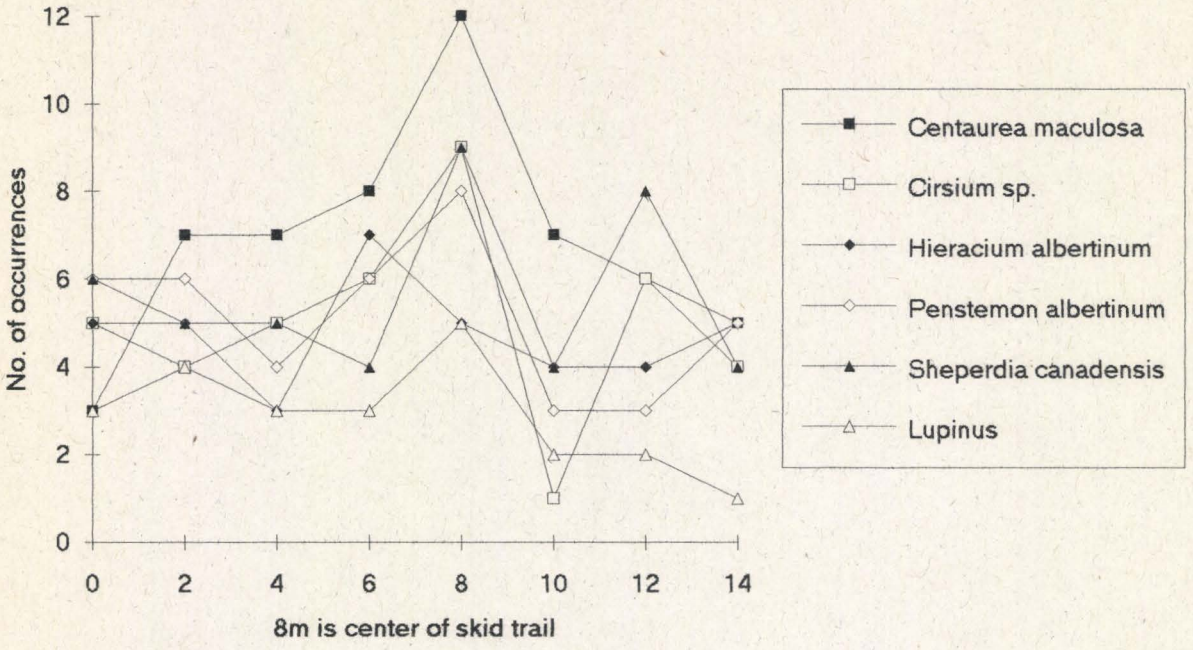


Figure 13. Species with negative response to skid trails

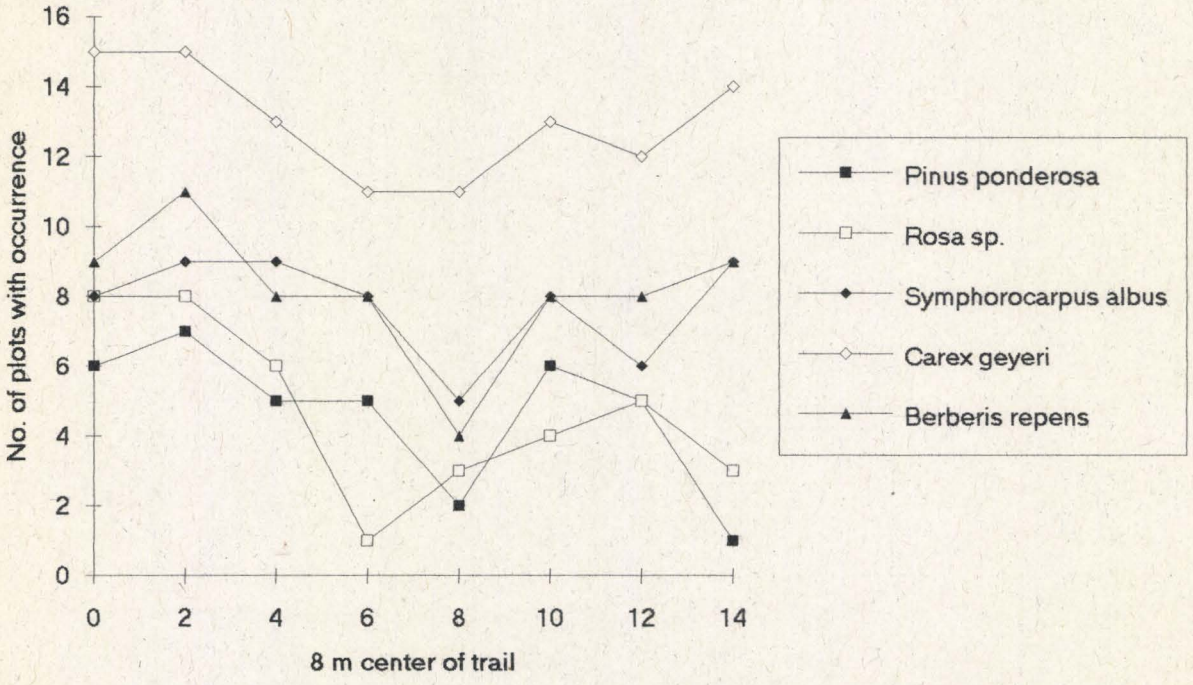
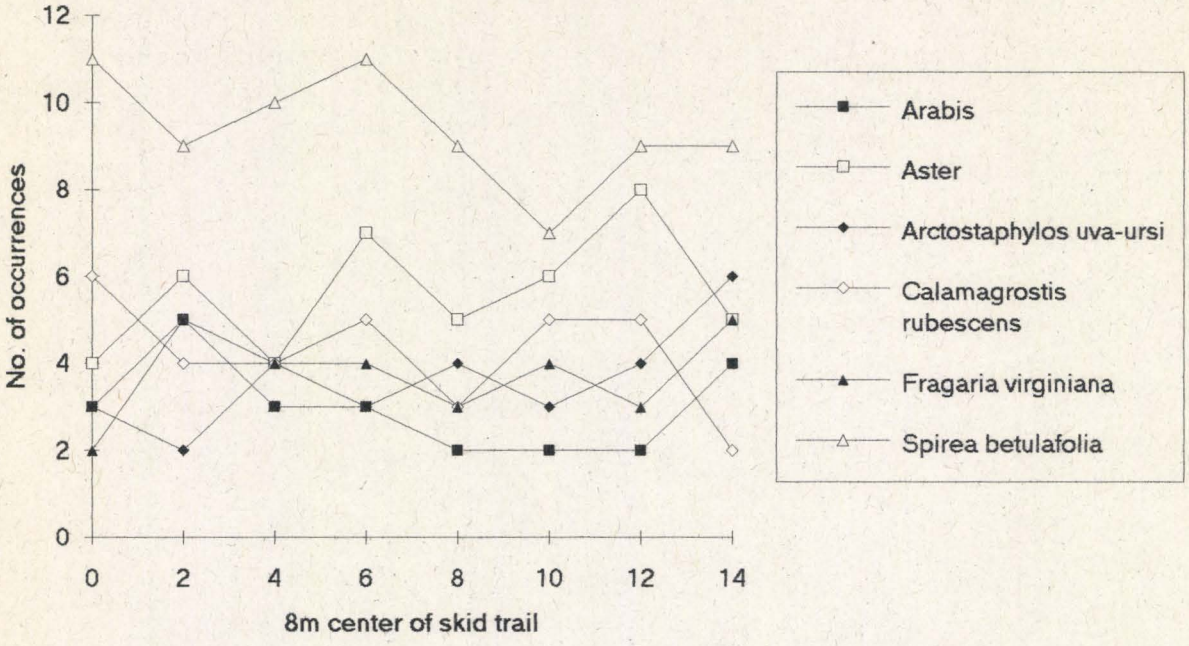


Figure 14. Species with ambiguous response to skid trails



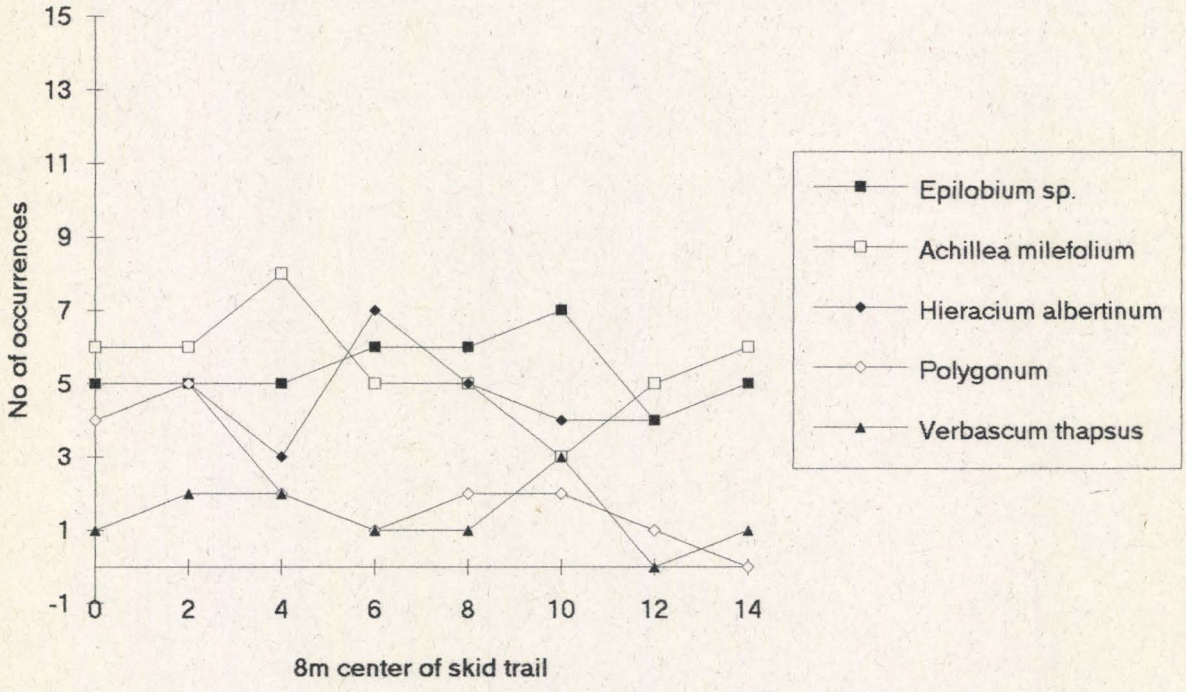


Figure 15. Knapweed Response to Fire and Skid Trails